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ENGINEERING SAFETY IN THE OCEAN MARGIN DRILLING PROGRAM.(U)
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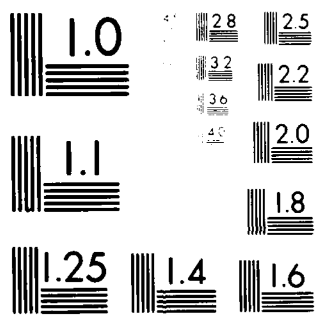

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Engineering Safety in the Ocean Margin Drilling Program

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A Report Prepared by the

Committee on Engineering Considerations for Continuation of Deep Sea Drilling for Scientific Purposes, Phase II

Marine Board

Assembly of Engineering

National Research Council

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Committee on Engineering Considerations
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Phase II
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National Academy Press
Washington, D.C.   1981

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This report represents work supported by Contract Number NSF C310 Task Order #388 between the National Academy of Sciences and the National Science Foundation.

Copies available in limited quantity from:

Marine Board
Assembly of Engineering
National Research Council
2101 Constitution Avenue, N.W.
Washington, D.C. 20418

Printed in the United States of America.

COMMITTEE ON ENGINEERING CONSIDERATIONS FOR
CONTINUATION OF DEEP SEA DRILLING FOR SCIENTIFIC PURPOSES
PHASE II

CLAUDE R. HOCOTT, Gulf Universities Research Consortium (Chairman)

WILLIAM L. FISHER, University of Texas at Austin

PAUL L. GASSETT, Consultant

WILLIAM M. NICHOLSON, Consultant

DANIEL A. NORTH, Exxon Production Company

PAUL R. PASLAY, Paslay, Inc.

LAWRENCE R. POMEROY, University of Georgia

DAVID S. POTTER, General Motors Corporation

PREFACE

For several years, the National Science Foundation (NSF) has been planning a program of ocean margin drilling that will involve the efforts of scientists and engineers from the universities, industry, and the U.S. government. The program will build on the successes of the Deep Sea Drilling Project, which has operated since 1968 and contributed evidence to the theory of seafloor spreading, continental drift, and plate tectonics. The Ocean Margin Drilling (OMD) Program is being developed to extend the contribution of scientific deep ocean drilling into the 1980's and beyond. The major objective of the OMD Program will be the study of the deep ocean margins, one of the last geologic frontiers on earth. This will require drilling at great depths with a full complement of well control equipment.

In planning the OMD Program, the NSF requested that the Marine Board of the National Research Council review engineering considerations for the continuation of deep sea drilling for scientific purposes. In 1978, a committee under the auspices of the Marine Board provided the NSF with an interim report in the course of an intensive survey of the background, scope, and proposed plans for drilling into the deep reaches of the ocean for scientific purposes, and alerted the NSF to important unanswered engineering questions concerning the feasibility of the entire project. In 1980, the committee completed the evaluation of the capability to conduct the proposed scientific program in an environmentally safe manner within acceptable limits of time and cost.

More recently, the NSF asked the Marine Board to provide technical reviews and assessments of engineering aspects of the OMD Program to assist in planning and implementation. A Committee on Engineering Considerations for Continuation of Deep Sea Drilling for Scientific Purposes, Phase II, was established under the auspices of the Marine Board of the National Research Council, to respond to the request. The committee consists of experts in geology, economics, marine engineering, offshore oil recovery, operations from mobile rigs, ship construction and conversion, well control, structural design, marine ecology, and program management of marine systems.

Two of the critical engineering issues identified for the committee's attention are personnel safety and environmental protection during deep sea drilling operations. These subjects were examined and discussed in a previous Marine Board report, Engineering for Deep Sea Drilling for Scientific Purposes, released in 1980. The reader is encouraged to refer to that report as one means of understanding safety systems, procedures, and training as these relate to drilling systems and platforms.

This report is the result of the committee's analysis of safety considerations in ocean margin drilling. It contains analysis, conclusions, and recommendations based on background information submitted to the committee for review and on the committee's deliberations held October 20-21, 1980, at the National Academy of Sciences.

In this report, the safety of personnel and protection of the environment are discussed with regard to anticipated requirements for adherence to U.S. regulations, including those of the U.S. Coast Guard and the U.S. Geological Survey, and the precedents established by the safety procedures in the present Deep Sea Drilling Program. In addition, the report discusses various aspects of environmental assessment and well control and identifies the role and importance of training in the OMD Program.

INTRODUCTION

Since the start of operations in 1968, the Deep Sea Drilling Program (DSDP) of the National Science Foundation, has achieved distinction by gathering scientific evidence to support and refine the plate tectonics hypothesis that portrays the earth as dynamic, with the seafloor and continents in motion. As part of its purpose, the DSDP has established a geological framework for the formation and distribution of natural resources, and investigated the effect of the changing surface of the seafloor on ocean circulation and climate. These objectives were pursued by drilling and coring more than 900 holes at 540 sites in the world's oceans over a 12-year period. The platform chosen, the *Glomar Challenger*, has the capability of drilling in water depths up to 20,000 feet (6,100 m) and can penetrate up to 2,500 feet (760 m) into the seafloor at that depth.

The operational and safety record of DSDP and *Glomar Challenger* are as impressive as the scientific attainments: 85 percent operational, no deaths or major personnel injuries, and negligible environmental harm resulting from drilling. Good luck cannot account for such a record. It is largely attributable to the care taken in site specific planning by the Joint Oceanographic Institutions for Deep Earth Sampling (JOIDES)* and its Safety Panel, and to the proficiency of the management and operating personnel of the Scripps Institution of Oceanography and Global Marine, Incorporated.

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*U.S. members of JOIDES are: the Lamont-Doherty Geological Observatory, Columbia University; University of Washington; the Woods Hole Oceanographic Institution; Scripps Institution of Oceanography, University of California; the Institute of Geophysics, University of Hawaii; the University of Rhode Island; the Rosenstiel School of Marine and Atmospheric Science, University of Miami; Oregon State University; and Texas A&M University.

The next program of deep sea exploration, the Ocean Margin Drilling (OMD) Program, is directed toward exploration, in the 1980's, of the ocean margin--the region of the earth's crust where the continental shelf slopes to the deep ocean abyss. The program will be funded jointly by the NSF and the U.S. petroleum industry. This is an ambitious undertaking in all aspects--scientific, technical, and managerial. Ten preliminary drilling locations have been chosen as a planning model (Table 1). These sites are in U.S. waters, international waters, and possibly within ocean realms of foreign countries.

The OMD Program, which has the objective of operating in 13,000 feet (4,000 m) of water and penetrating to 20,000 feet (6,100 m) beneath the seafloor, presents a major technical challenge: to be able to drill for cores at more than twice the current capability. Moreover, the sedimentary character of the passive margins, which are emphasized in the OMD Program science drilling objectives, presents a requirement to be able to plan, operate, and safely control drilling operations in geological conditions that may include high-pressure hydrocarbon-bearing structures. The desirability of avoiding such situations has been voiced by the NSF and strongly recommended by the committee in its Phase I final report, "Engineering for Deep Sea Drilling for Scientific Purposes" (1980). Provisions to control the drilling operation in such situations are essential.

The OMD Program drilling system, which includes the proposed support ship Glomar Explorer, its crew and operating personnel, must adhere to standards of safety for dealing with a potential problem of great severity: the sudden release of high-pressure gas or fluid that could enter the drilling column from the well hole in the seabed and rise through the water column (through the drill string and riser*) to the drill ship. Use of the best available technology, at the depths proposed in the OMD Program, will be essential to monitor the flow of fluids into and out of formations. While systems to monitor and respond to such events exist and are under continuous development, accelerated development and testing are needed to meet program goals. An adequate quality assurance program for this is essential.

This report addresses the subject of safety for the NSF Ocean Margin Drilling Program, with emphasis on avoiding sudden high-pressure changes and penetrations into hydrocarbon-bearing formations. The concern for safety always includes the protection of personnel and the environment in the broadest sense: viz. that it

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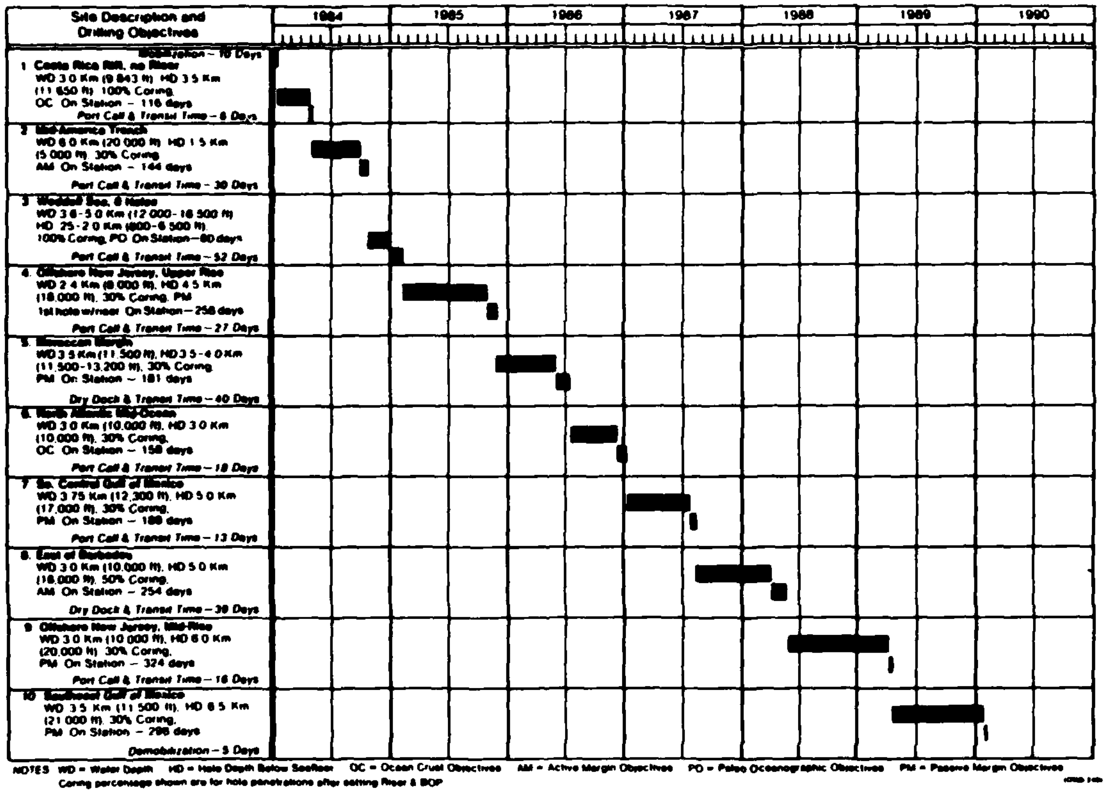
*Riser: A long tubular member that is situated around the drill string and extends from a supporting and tensioning device on the ship or platform to the ocean floor. The annular space between the drill string and riser provides a return passage for the drill fluid and for the "cuttings" that the bit removes as it drills into the earth.

TABLE 1
THE OCEAN MARGIN MODEL DRILLING PROGRAM



Source: National Science Foundation, Ocean Margin Drilling Program, Volume I, Program Overview, December 1980

is intimately related to the use of the best available technology, the quality and training of operating, support, and scientific personnel, and the implementation of safe operational practices. All these aspects of safety are discussed in this report, albeit briefly. However, the first standard of reference is the federal safety regulations that the NSF must meet or, in some cases, choose to adhere to; these are also discussed, and a summary of regulations is provided.

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SECTION I
SAFETY AND DEEP SEA DRILLING
REGULATIONS AND PRECEDENTS

The Ocean Margin Drilling (OMD) Program proposed for the 1980's will be a unique endeavor--technically, as reflected by its depth objectives, and administratively, as demonstrated by the marriage of government and industry to provide financial support and program engineering guidance. In undertaking this endeavor, the U.S. government and industry have established guidelines to reduce risk and enhance the safety of personnel and protection of the environment. The guidelines take the form of the regulations concerning outer continental shelf (OCS) exploration and development and the rules and precedents of good safety planning and practice undertaken by the Deep Sea Drilling Program in its operations with the Glomar Challenger. This section discusses present regulations and precedents and relates them to the Ocean Margin Drilling Program.

Regulations Applicable or Pertinent to Ocean Margin Drilling

Some regulations of the U. S. government and those established by international conventions and protocols apply to the category of research vessels and drilling platforms that are intended for use in deep-sea drilling for scientific purposes--regulations governing, for example, safety of navigation, life at sea, vessel inspection and certification, requirements for trained mariners, and so on.[1] A second category of regulations is pertinent--ones formulated by the U.S. Geological Survey, say, to regulate exploratory drilling for petroleum on the outer continental shelf (OCS).

A summary discussion of these two categories of regulations is provided so that a basic understanding of applicable and pertinent regulations may be developed. The committee's principal assumption in its selection of these regulations for discussion is that the design and operation of the research vessel/platform and drilling system should, at a minimum, conform so far as possible to the regulations governing a drillship or platform conducting exploratory drilling on the outer continental shelf of the United States. Even so, it is realized that few, if any, OMD Program coring sites are planned for the outer continental shelf. While the research

vessel/platform is subject to these regulations if drilling is conducted on the outer continental shelf of the United States, it is not subject to USGS drilling regulations when operating in the ocean beyond the outer continental shelf. Nevertheless, the panel assumes that all operations of the OMD Program will adhere to the technical principles and the intent of OCS requirements. A brief summary of international conventions and agreements is provided in Appendix A.

Regulatory Responsibilities of Agencies

The regulation of exploratory drilling on the outer continental shelf is the responsibility of several federal agencies: the U.S. Environmental Protection Agency (for guaranteeing the quality of ocean water and setting standards for allowable discharges); the U.S. Geological Survey (for expeditious and safe production of natural resources); the U.S. Coast Guard (for the safety of life at sea, navigation, actual or threatened pollution of navigable or OCS waters, the integrity of vessels and mobile drilling platforms), the Bureau of Land Management (for specifying the terms of the use of federal lands), and the U.S. Army Corps of Engineers (for structures placed or anchored in navigable waters in the outer continental shelf area). Under the circumstances, it is not unreasonable to expect overlapping lines of authority among the agencies. To their credit, the agencies have resolved their areas of responsibilities through memoranda of understanding. The assigned areas tend to follow practical considerations of enforcement. For example, the Occupational Safety and Health Administration (OSHA) and the U.S. Coast Guard have concluded a memorandum of understanding that calls for the Coast Guard to promulgate regulations governing workplace safety in oil and gas operations on the outer continental shelf and the Coast Guard to take account of OSHA's general standards in this. In the event of violations of OSHA workplace standards, the Coast Guard is required to report the incident to OSHA. The agreement acknowledges the Coast Guard's long history of responsibility for maritime safety, and (though not explicitly stated) the Coast Guard's practical ability to conduct inspections on the outer continental shelf.

The U.S. Geological Survey regulates the safety of drilling and production on the outer continental shelf under the Outer Continental Shelf Lands Act of 1953. Before 1953, the industries involved in oil and gas exploration and production had recognized the need for standardization of equipment and practices, and instituted organizations and networks of communications to effect them. The government's regulatory process amplified those efforts. A number of the regulatory requirements also apply to drilling in the passive margins for strictly scientific ends, the principal concern being well control.

The U.S. Geological Survey and the U.S. Coast Guard concluded a memorandum of understanding in 1980. It recognizes that the Geological Survey possesses the expertise and experience to regulate drilling and production and the Coast Guard to oversee maritime safety. Under the division of responsibility, the Coast Guard is responsible for mobile drilling ships as vessels, while the U.S. Geological Survey regulates drilling operations.

Regulatory Practices

In regulating the operation of vessels, the Coast Guard acquires detailed knowledge of the design, construction, outfitting, operation, movements, and history of each by reviewing plans, conducting inspections of firefighting systems and emergency survival equipment, and in reviewing periodic reports. Inspecting officers can establish a collaborative relationship to achieve compliance and overall safety. Were an ocean margin drill ship to be subjected to this review procedure (and it is likely that it will), the features likely to be of greatest interest and concern to the Coast Guard would be its structural adequacy in view of the structures to be hung from the ship, emergency break-off and other contingency plans, and operating procedures. The Coast Guard regulations listed in both 33 CFR Part 19 and 46 CFR Part 6, "Waivers of Navigation and Vessel Inspection Laws and Regulations," state that waivers are granted only in the interests of national defense.

The U.S. Geological Survey regulates oil and gas operations through requiring that operators prepare operating plans for USGS review, and obtain permits for specific operations. In this planning and permit process, the operator makes a wide variety of technical operating and environmental information available to the regional office of the Geological Survey for review and approval. The regional office exercises discretion over a considerable range in deciding the terms of operation as evidenced in plan and permit approvals. Similar oversight of scientific drilling within U.S. jurisdiction is ordinarily provided at USGS headquarters and not in a regional office. A distinct section of regulations states the requirements for scientific drilling operations on the outer continental shelf (30 CFR 251).

The U.S. regulatory regime for ocean drilling does not extend beyond U.S. jurisdiction. However, the process of regulatory review provides a discipline to program planning requiring thorough understanding of ship characteristics, environment, contingencies, and crew and supervisory training. Therefore, the Ocean Margins Drilling Program needs to consider the intent of the regulations discussed here as well as the valuable aspects of the specific regulatory program.

In view of the present OMD Program plans to convert and use the Glomar Explorer, this discussion regarding regulations assumes the Ocean Margin Drilling Program drilling platform will be a drill ship.

Environmental Regulations

The environmental regulations applicable to drilling operations on the outer continental shelf of the United States are written and enforced by the Environmental Protection Agency under the authority of the Clean Water Act, as amended (33 USC 466), and by the U.S. Geological Survey under the authority of the Outer Continental Shelf Lands Act, as amended (43 USC 1801). The Clean Water Act forbids the discharge of oil on the oceans generally: the Environmental Protection Agency sets the allowable concentration of oil in discharges of produced water or drilling fluids at 48 mg/l (30-day average; maximum for any one day, 72 mg/l).

Drilling operators on the outer continental shelf apply to the regional office of the Environmental Protection Agency (EPA) for a permit to discharge under the National Pollutant Discharge Elimination System (NPDES). There are precedents in this process for the obtaining of general permits covering an entire class of operations or operating area.

The National Oil and Hazardous Substances Pollution Contingency Plan, written and periodically revised by the Council on Environmental Quality, sets out the conditions and requirements for response and countermeasures to be taken in case of threatened or actual pollution. If OMDP operations were undertaken within U.S. jurisdiction, the Geological Survey would require the preparation of an oil spill containment and cleanup contingency plan, including provisions to report oil spills to the U.S. Coast Guard. In the case of OMD operations, responding to an oil spill would be a federal responsibility. The U.S. Coast Guard would be in charge of containing and cleaning up the spill. The Coast Guard might request U.S. Navy assistance in this.

International and regional agreements and conventions have been established to limit the pollution of the oceans. These are summed up in Appendix A.

The most significant source of potential pollution in research drilling is a blowout of the well, and well control is the most significant countermeasure. Well control is discussed in Section II of this report.

Drilling Operations and Regulations

The dangers associated with blowouts range from mild to life- and property-threatening. The industry and the U.S. Geological Survey have focused attention on this area of operations for several decades. The means of controlling the well center first in ascertaining, as thoroughly as possible, the nature and characteristics of the formations to be drilled. Within U.S. jurisdiction, the Geological Survey obtains such information for review and approval by requiring that operators prepare a drilling plan for each well. Preparation of a drilling plan provides an opportunity for a site-specific safety

evaluation. Areas where there is a possibility of high-pressure conditions conducive to blowouts can be identified and avoided. Other aspects of well control that can be reviewed at this time include determining whether proposed mud, casing, and drilling programs are likely to meet anticipated conditions.

Another means for maintaining well control is prompt detection and reaction to kicks (any entry of formation fluids into the wellbore sufficient to call for shutting in the well under pressure). Measures and equipment designed to deal with kicks comprise the back-up to maintain well control (diverters, blowout preventers, stripping or snubbing if the drillstring is not on the bottom, circulating out the kick).

Measures and equipment to regain control after a blowout has occurred include such actions as circulating heavy mud (if possible), capping the well, drilling relief wells, and others. Nature may plug the flow by bridging.

Well control accidents are chains of events that usually involve failures in (or by) equipment, people, procedures, and adherence to procedures. Forces and circumstances of nature, the interaction of men and machines, decisions, or accidents are all involved. No single cause and effect can be singled out for preventive efforts. They are all important, and careful continuous attention is necessary to recognize warning signals in a timely way. The general plan of regulations are arranged as responses to well control problems in Table 2.

Two specific concerns related to drilling not covered in Table 2, should also be noted in a review of regulations. All deep boreholes drilled for research purposes on the OCS must be permanently plugged and abandoned (30CFR251.6-2(C)(2)(g), as stipulated in OCS Order 3-2, "Plugging and Abandonment of Wells." Also of concern is hydrogen sulfide, which may be encountered while drilling. OCS Order 2-5 states that the measures and practices spelled out in the USGS Outer Continental Shelf Standard #1 "Safety Requirements for Drilling Operations in a Hydrogen Sulfide Environment," will be followed.

The safety and regulatory requirements related to a hydrogen sulfide (H_2S) environment are particularly important in view of its potential threat to personnel. A recent blowout resulting in 19 fatalities from uncontrolled release of H_2S gas from a well being drilled in the Persian Gulf emphasizes the concern. Fortunately this has been an infrequent problem in drilling operations in U.S. waters. Still it is a matter to be included in the site selection process and in establishing operating procedures. Once operations begin contingency plans should include the possibility of unexpected exposure and detailed emergency procedures for reestablishing control, protection of personnel, and plugging of the well. In addition, personnel safety requires employment of surface detectors to warn of the presence of H_2S in the mud system.

TABLE 2
WELL CONTROL IN DRILLING: Technical and Regulatory Response by Problem Type

DRILLING

Potential Well-Control Problem	Design and Execution: Good Practice	Equipment and Instruments	Applicable Regulation
Fluid pressures, mud weight, fracture pressures	Use best available geological and geophysical data; calculate fracture gradient	Seismic, acoustic, real-time sampling; analysis and interpretation important	OCS Order 2-1.1 Must submit data with application for permit to drill.
Casing program: design and integrity	Set casing at depths to ensure/restore wellbore integrity; to meet needs of deeper penetration	Casing grades, cement to meet maximum pressure needs of kick	OCS Order 2-1.1 Must submit plan and specifications with application for permit to drill.
	Hydraulically test integrity of casing, cement job, casing-seat formation		OCS Order 2-3 Required setting depths for casing, formation fracture gradients, tests.
Maintaining full hole	Adequate mud program		OCS Order 2-1.1 Must submit the application for permit to drill; OCS Order 2-6 "mud program" requirements must be met.
	Replace pipe volume with mud volume in tripping	Trip tank, instrumentation	
	Workers alert to warning signals; understand principles of pressure balance, proper procedures		OCS Order 2-7 USGS standards for training in well control.
	Work to cure lost circulation problems while adding mud to annulus	Standby volume of mud	OCS Order 2-6 "mud program," and OCS Order 2-1.1 mud program plan must be submitted with application for permit to drill.
	Control rheology of mud to minimize surge and swab, control pipe speed	Observe surge and swab in trip-tank changes; test if possibility of swabbing	Training, mud program.
Shallow gas	Avoid known areas of shallow gas	High-resolution techniques	OCS Order 2.3 Shallow hazards survey required, lease stipulations.
	Drill slowly, keep bit on bottom, use diverter	Diverter	OCS Order 2-5 BOP requirements, referencing API Standard for diverters.
Lost Circulation	Awareness of signals and interpretation; formation fracture potential; rheology of mud, drill string clearance, design mud weight	Pit-level instruments, returns rate	OCS Order 2-5 BOP requirements; OCS Order 2-6 mud program.
		Training	OCS Order 2-7 and standard.
	Control pipe speed in hole		

TABLE 2 (continued)

WELL CONTROL IN DRILLING: Technical and Regulatory Response by Problem Type

DRILLING Potential Well-Control Problem	Design and Execution: Good Practice	Equipment and Instruments	Applicable Regulation
Gas-cut mud	Flow check: continue drilling if no flow; if flow, shut in, circulate bottoms up through choke line. Stop to check, allow kick to expand, choke as required; raise mud weight as required	Pit-level instruments, returns rate, drill pipe pressure gauge, choke manifold and control console, BOP, mud system	As above.
Fluid influx	As above	As above	As above.
Equipment operability	Routine function and integrity tests, vigilant inspection and maintenance of well-control equipment		OCS Order 2-5 BOP requirements--testing, actuation specified; inspection and maintenance required. OCS Order 2-3.6 Pressure testing of casing.
	BOP and shut-in drills for crews		OCS Order 2-7 drills.

Fire Prevention and Firefighting

The pattern of U.S. government regulation of fires and explosions comprises research and standard-setting by professional organizations such as the National Fire Protection Association, Underwriters Laboratories, Inc., and federal agencies such as the National Bureau of Standards, testing by suppliers and operators, and the application of proven technology, practices, and standards by regulatory agencies. An additional element in the regulation of fires and explosions in operations on the outer continental shelf has been the continuing efforts of industry to improve the technology of well control, and that of drilling systems, to minimize the potential and consequences of operational fires or explosions.

The design of drill ships such as the Glomar Explorer incorporates specific measures directed against all elements of the fire triangle (fuel, a source of ignition, and oxygen). Table 3 sums up required structural fire protection, and prevention measures directed to sources of ignition and areas of hazards. It is important to recognize that some ignition sources such as helicopters, boats, static electricity, and lightning, can neither be modified nor eliminated.

The U.S. Coast Guard is responsible for structural fire protection, fire prevention, firefighting, and training on drill ships, and for the safety of life at sea (see the subsequent subsection, "Abandonment"). The U.S. Geological Survey is responsible for fire prevention, firefighting, and training for well control in drilling operations. Within U.S. jurisdiction, both agencies require submission of plans for review and approval.

The most common cause of operational fires in drilling is entrained gas. Mud is mixed in the mud-room and pumped down hole. When the mud returns to the surface, it contains drill cuttings and, possibly, liquids and natural gases from the formation that may have mixed with it. This mud is passed through a shale shaker to screen out the larger cuttings, and through a desander to remove sand and fine drill cuttings. At this point, it is dumped into the mud tank to be reconditioned and reused. Throughout the path of up-hole mud flow entrained gas is released to the atmosphere. Whenever gas is anticipated, a degasser is used to remove most of the gas before it enters the shale shaker and desander in the mud-room. Control of the entrained gas consists of safe venting of the degasser, and liberal ventilation of the mud-room. However, weather and atmospheric pressure changes can cause vented gas to collect in areas that are ordinarily gas-free. To guard against such unplanned gas concentrations both the U.S. Coast Guard and the U.S. Geological Survey designate certain areas as hazardous. Within these areas, ignition sources must be minimized by various means, including:

- No smoking in the area.
- Low-tension ignition systems for internal combustion engines.

TABLE 3
REGULATIONS FOR FIRE PROTECTION APPLICABLE TO DRILL SHIPS

	U. S. Geological Survey (Drilling)	U. S. Coast Guard
Structural Fire Protection	Equipment, procedures, plan of operation, with special attention to safety, must be described and approved, 30 CFR 251, OCS Order 2	Construction portfolio must be submitted; plans must meet detailed specifications for hull superstructure, structural and boundary bulkheads, decks and deck separations, accommodation spaces, hatches and tonnage openings, etc. Ship must pass inspection and certification procedures. 46 CFR Subchapter I-A
High-pressure Piping	OCS Order 5-5.1.2--All flowlines from wells to be equipped with high- and low-pressure shut-in sensors, API standards	46 CFR 58.60-1(g), 58.60-7--Must meet ANSI standards
Pressure Vessels	OCS Order 5-5.1.1--In accordance with ASME Code	46 CFR 60-3--Must meet standards of Coast Guard, including ASME Code
Hazardous Materials		46 CFR 109.557, 109.559--flammable liquids, explosives, radioactive materials may not be carried in bulk, unless allowed by Certificate of Inspection, then only in accordance with specifications; used only as authorized by person in charge
Machinery	OCS Order 5-5.1.5--Engine exhaust insulation and personnel protection to comply with API standard; exhaust piping from diesel engines equipped with spark arresters	46 CFR 108.187--Ventilation for brush-type electrical motors, NFPA standard 46 CFR 58.10-10, 58.10-15--Neither air inlet nor exhaust in enclosed spaces, semi-enclosed spaces, nor near possible sources of discharging gases (drill floor), as specified
Helicopter Decks		46 CFR 109.529--Designates clearance, loadings, surface, drainage, etc.
Helicopter Fueling		46 CFR 109.577--Only by designated person familiar with fueling and safety procedures
Electricity		46 CFR 250.56--Only intrinsically safe, approved electrical equipment in designated semi-enclosed spaces
Training in Firefighting		Coast Guard/Maritime Administration Policy Statement concerning Qualifications of Crews of United States Merchant Vessels, 6 September 1974 (shared responsibility)

- Intrinsically safe electrical controls (i.e., non-sparking).
- No welding, cutting, or grinding.
- Explosion-proof fixtures.
- Positive pressure ventilation when sparking cannot be prevented.

The following areas are designated as hazardous by both the Coast Guard and Geological Survey.

- Mud-rooms.
- Drill floor to a height of 3 meters.
- Areas below the drill floor within 3 meters of a possible gas release.
- Any area connected with the above that may accumulate gas.

Nevertheless, fires do occur. The fire-extinguishing systems required of drill ships are set out in Table 4.

Abandonment

Abandonment becomes necessary when the prevention and control systems fail, the protective systems fail, and loss of life is imminent. Abandonment on the ocean entails leaving one life-threatening situation for another. The first problem in abandonment is effecting a safe transfer from a relatively motionless structure to a constantly moving sea. The second is protecting the lives of survivors until they can be rescued. Regulations governing abandonment are set out in Table 5, including those requiring drills, assignment, and compliance with responsibility to ensure the crew's knowledge of what to do in case of emergencies, and establishing the chain of command. These regulations are stated in general terms, and enforcement procedures are usually limited to checking logs for the required number of drills (annual Coast Guard inspections include witnessing drills). A comparison of the abandonment regulations with those governing the training of drilling personnel in well control is instructive. The latter set of regulations (but not the former) requires training in approved schools, hands-on experience, certification, and periodic refresher courses.

Testing, Inspection, and Maintenance of Survival Equipment

According to a study of U.S. merchant vessels commissioned by the U.S. Coast Guard, inspections continue to reveal, besides the confusion over emergency duties and stations, and the lack of training cited previously, "inoperative or badly corroded survival equipment."[2] The regulations governing tests and maintenance of survival equipment (listed in Table 6), the report maintains, do not constitute a well-defined program for survival and firefighting equipment, nor do they provide a means of keeping written records for

TABLE 4
FIRE EXTINGUISHING SYSTEMS REQUIRED BY U. S. COAST GUARD REGULATIONS

General	Fire Main System, 46 CFR Ch.I, Subpart D
Production-handling Equipment	"
Drill Floor	" , plus two portable extinguishers
Gas- and oil-fired Boilers	Fixed CO_2 system; two portable extinguishers (CO_2 or dry chemical), one extinguisher in each space for electrical fires, 46 CFR Ch.I, Subpart D
Corridors	Portable extinguishers, water, 46 CFR Ch.I, Subpart D
Quarters	"
Radio Room	Portable extinguisher for electrical fires, 46 CFR Ch.I, Subpart D
Galleys	Portable extinguishers, CO_2 or mechanical foam, 46 CFR Ch.I, Subpart D
Electric Motors or Generators	Portable extinguishers for electrical fires, 46 CFR Ch.I, Subpart D
Helicopter Landing Decks, Fueling Facilities	Portable extinguishers, CO_2 or mechanical foam, 46 CFR Ch.I, Subpart D
Cranes	"
Miscellaneous	Fireman's outfits and fire axes, 46 CFR Ch.I, Subpart D
Drills	At least once a week, all personnel must report to fire stations, bring out equipment, start each fire pump, 46 CFR 109.337

TABLE 5

REGULATIONS GOVERNING EMERGENCIES AND ABANDONMENT ON DRILL SHIPS (U.S. COAST GUARD)

Alarms	General alarm bell, marked "Go to Your Station," 46 CFR 108.623,625 Locations of contact-makers for general alarm system, 46 CFR 113.25-5	Means of Escape	Two means of escape, each working space and weather deck to water level, access to lifeboats, detailed specification for vertical ladders, no dead-end corridor etc., 46 CFR 108.151 through 108.167
Distress Communications	Portable radio (international voyages) transferable to lifeboat, 12 flares, emergency position indicating radio beacon, approved type (EPIRB), 46 CFR 108.519, 521, 523	Chain of Command, Station Bill, Responsibility	"Master or person in charge" Master or person in charge ensure that persons on unit and all visitors familiar with duties and stations in emergencies, post station bill, assign seats in lifeboats, etc., 46 CFR Subpart E
Emergency Lighting and Power	Emergency lights, final emergency source loads, 46 CFR 112.05-10, 112-15-5		
First Aid			
Lifeboats, Liferafts, Survival Capsules	One lifeboat (30 people or less on board, two if more). Liferafts to accommodate 100% of personnel, detailed specifications of release, launching, and provisioning, location, etc., 46 CFR 108-503 through 108.655. (Def. of lifeboat includes survival capsule, 46 CFR 108.501)	Training and Drills	Boat drill once weekly, 46 CFR 109.215
Life Preservers, Ring Life Buoys, Other Lifesaving Equipment	Life preservers for 125% of people on board meeting stated specifications, at least eight ring life buoys with waterlights and smoke signals, 46 CFR 108 46 CFR 108.514,515		

TABLE 6

COAST GUARD REQUIREMENTS FOR TESTING, INSPECTION, AND MAINTENANCE OF SURVIVAL EQUIPMENT

ITEM	MOBILE DRILLING UNITS
General	All firefighting and lifesaving equipment maintained in operative condition, 46 CFR 109.301
Fire Extinguishers (Portable)	Tested and inspected yearly, 46 CFR 109.223 Marine-type label, 46 CFR 162.028-4 Spare charges for 50% of extinguishers, 46 CFR 108.495
Lifeboats	Contain maintenance and repair instructions, schedule of periodic maintenance, diagram of lubrication pts., and recommended lubricants, log of records of inspection and maintenance, 46 CFR 108.503 Partially lowered, engine started, once weekly (boat drill), 46 CFR 109.215 Cleaned, inspected, fuel changed once yearly, 46 CFR 109.217 Radio tested, battery charged weekly, 46 CFR 109.217
Inflatable Life Rafts	Servicing and complete inspection of required equipment by marine inspector once yearly, 46 CFR 160.051, 46 CFR 109.219
Life Floats	
Work Vests	
Alarms, Distress Signals	Alarms inspected and tested within 12 hours of getting under way and once weekly, 46 CFR 109.201 Each distress and smoke signal replaced within 36 months of manufacturing, or by date of expiration, 46 CFR 109.317
Emergency Lighting and Power Systems	Tested once weekly, emergency generator once monthly, storage battery every six months, 46 CFR 109.211
Emergency Position Indicating Radio Beacon	Tested once monthly, battery replaced by date indicated, or after use, 46 CFR 109.208, 307
Line-Throwing Equipment	Tested every four months, 46 CFR 109.207
Records	Logbook--include time and date of each required test, condition of equipment, date of lifeboat inspection and condition of winch, 46 CFR 109.433 Record of all inspections of firefighting equipment to be maintained on board, 46 CFR 109.435 Report to be submitted of all repairs or alterations to emergency equipment, 46 CFR 109.425

the status of accomplishment. While the regulations are generally complied with, the two most important areas of neglect appear to be the lubricant and corrosion control for lifeboat launching gear. The report notes that the Shipboard Maintenance and Repair System developed by the U.S. Maritime Administration has been used with success by some drilling companies. These considerations will be of special importance to the NSF's Ocean Margin Drilling Program because of the remote locations and long times on-station envisioned.

Safety Planning in the Deep Sea Drilling Program

Over ten years of drilling and coring in the Deep Sea Drilling Program has produced a history of scientific successes and, concurrently, a record of outstanding safety. A portion of this record may be attributed to the independent, site specific operational assessments by the JOIDES Safety Panel.

The idea of an independent review of all locations proposed for the Deep Sea Drilling Program came originally from the National Science Foundation and the Program itself, and was put into practice in early 1970. The need for an independent safety review of every drilling site became apparent in 1968 when drilling operations in the Sigsbee Knolls area of the Carribean encountered significant hydrocarbons (five feet of oil-saturated core and sulfur). This made the NSF aware of the dangers inherent in assuming or presupposing the geology of proposed operations sites, and led to the establishment of an independent safety review of all proposed deep sea drilling sites and also the preparation of on-site safety contingency plans. Every site proposed since 1970 has been reviewed by a safety panel, and none has been drilled without its specific approval.

The philosophy of such a review follows a principle of "negative prospecting;" that is to say, knowing the geological conditions required to form an accumulation of oil or gas, i.e., a source area with proper thermal history, a migration path, a reservoir and a trap. The safety panel tries to avoid locations at which these conditions exist. There are no guarantees, of course, but with good data, a knowledgeable safety panel, and a conservative approach, the risk has been reduced to a minimum.

In actual practice, safety concerns are built into every part of the program planning system. When working groups within the JOIDES organization first began discussing areas in which they might wish to drill, the knowledge that any drilling site chosen must pass a "final safety review" imposed some limits on their choices. When "candidate sites" based on available geophysical and geological data are selected, this material is first presented to the safety panel on an informal basis. This preview is intended to eliminate particularly risky sites before any further survey time and money is spent on them. In some cases, the safety panel may recommend that safer locations be chosen, or that additional data be gathered to demonstrate acceptable structural positions. For other locations, the panel may suggest that further surveys for safety are unnecessary, and that the data available are sufficient for final safety review.

Final safety review is generally held from one to three months before a particular drilling project begins. This may be six months to one or two years after the safety preview, and additional survey data may have been gathered in the interval. About two weeks before the safety review, each member of the safety panel receives a package containing the basic information on each of the drilling locations to be reviewed. In addition to standard forms filled out by the site proponents, there may be location maps, bathymetric maps, structure maps, isopach maps, geophysical records sections, and any other information that will provide the panel members with background on the geology of the proposed drill sites. In addition to these data, proponents may bring to the final safety review essentially their entire working collection of geophysical data.

During the safety review, the proponents for each site display the specific data set, explain the operational plan, and answer questions from the safety panel. Discussion of a site may last for a few minutes to half a day, depending on its complexity, but eventually the safety panel reaches a consensus and either approves, disapproves, or recommends changes. Changes may involve a new location for safer structural position, a drilling depth limitation, or some special operational constraint such as use of a pressure core barrel or careful examination of each core brought onboard before coring ahead in the next interval.

Finally, each of the chief scientists, at least one of whom is always present at safety review, is given a kind of "post-mortem" form to fill out after each safety-approved hole is finished. This form compares the operational and geological conditions proposed and predicted at safety review with those actually carried out or encountered in drilling. It is, in effect, a final report back to the safety panel.

As effective as the safety review process has been in the Deep Sea Drilling (DSD) Program, the Ocean Margin Drilling (OMD) Program differs in a number of ways that may affect the timing and methodology of a safety panel. The OMD Program faces far greater challenges associated with increased drilling depth and penetration. Similarly, the OMD Program must consider its investment in each well, approaching an order of magnitude more in time and cost compared to the DSD Program, and, as a result, the committee observes that assessment of risk should be emphasized in the OMD Program.

Special Considerations

The OMD Program pushes the application of technology beyond the expressed or implied scope of OCS regulations in matters regarding well control and depth of drilling, as well as in contingency planning, training, and operations command and control. The committee has considered the special emphasis that must be placed on these matters and found only one area--the provision for well control during

drilling operations in the first 6,000 feet beneath the seafloor at ocean depths up to 13,000 feet--where there is no adequate regulatory guidance for a technical requirement. The next section discusses this problem and the technical options available to NSF.

The evolution of OCS regulatory requirements in regard to personnel safety and drilling has encompassed hard lessons in safety problems and industry experience. Therefore, the OCS regulatory base is the best demonstrated standard to encourage continued safe practices. Further safety assurance goes beyond regulations into such areas as program management and ocean margin drilling training.

SECTION II
PROVIDING FOR THE SAFETY OF OCEAN MARGIN DRILLING

This section discusses the issues relative to the safety of ocean margin drilling that the committee has identified. These pertain to:

- The environmental effects of ocean margin drilling and the necessity of assessing such effects on the the marine environment.
- Well control in the course of operations.
- The selection, motivation, training, experience, and qualifications of personnel to carry out safe ocean margin drilling operations.

Environmental Effects

The Ocean Margin Drilling (OMD) Program calls for the drilling of ten holes on active and passive continental margins and in oceanic crust. Some of these scientific boreholes will be located within the jurisdiction of other nations. Others, including at least one Antarctic ocean drilling site, will be located outside the jurisdiction of any nation.

Pollution incident to these operations may include the discharging of drilling fluids and other materials and debris into the oceans. While it is not the intent of the program to discover oil or gas, the accidental spilling of oil is possible and must be considered.

It is necessary to determine the environmental effects of ocean margin drilling. Indeed, the assessment of the environmental effects of ocean margin drilling is required.[3]

Environmental Effects of Ocean Margin Drilling

The Ocean Margin Drilling (OMD) Program will consist of ten holes drilled over a very large area of deep ocean beyond the continental shelf. This environment is greatly different from that of the outer continental shelf; several of the major differences are discussed below. The contrast demonstrates that extrapolation from outer continental shelf data to the deep sea environment is not likely to produce valid information. The water depth in which the OMD Program will operate ranges from 3,300-13,000 feet (1,000-4,000 meters), as opposed to a maximum of 600 feet (180 meters) on the shelf. At the depths of the OMD Program operations, solids and fluids released at the surface in the course of operations, such as drilling muds and cuttings, will be widely dispersed over a large area. The volume of water and area of bottom related to drilling could be at least two orders of magnitude greater in the OMD program wells than in OCS wells. This reduces the potential unit area of impact proportionately; dilution of sediment and potential toxics would be one hundred times greater. There would also be greater opportunity for chemical co-precipitation of heavy metals in sea water. In effect, impact on the pelagic community will be minimal. Impact on the slope or abyssal benthos should be minimal because of wide dispersion of sediment, except in the immediate vicinity of the hole.

From the viewpoint of environmental protection, the one major issue is well control and the accidental spillage of petroleum. Since the capability to mount an effective containment and clean-up effort in the areas of OMD operations does not exist, the only practicable line of defense against an oil spill is proper well control. The loss of fluids or major release of H_2S gas will have a significant impact in those areas where these fluids or gas are highly concentrated. Formation water will spread out along the ocean floor with possible deleterious impact on benthic fauna in areas of high concentration. Any petroleum released would probably rise to or near the surface, where it would weather.

Assessing the Environmental Effects

The question arises as to what degree of environmental assessment is necessary to satisfy the dictates of the National Environmental Policy Act, and, more important, to improve the safety of ocean margin drilling.

An Executive Order requires that federal agencies prepare environmental impact statements for major federal actions that have significant environmental effects on the "global commons" (e.g., the oceans and Antarctica). While the significance of the environmental effects of ocean margin drilling can be debated, the potential

consequence of marine pollution is certainly present. By way of analogy, a programmatic environmental impact statement was prepared on the Deep Sea Drilling Program (operations of the Glomar Challenger) in 1975. It has sufficed for all program activities since that date.

It appears appropriate for the NSF to prepare a programmatic environmental impact statement (EIS) on the OMD Program. This EIS should address broad-based effects on the deep ocean beyond the shelf. However, it is not as clear that there is likely to be any beneficial result from preparing site-specific (one for each site) impact statements in addition to the programmatic analysis.

While it is true that the OMD Program's impacts will be site specific, they will also be negligible. The only instance in which this would not be the case is in the case of a blowout, and these cannot be predicted on a site-specific basis. If, for reasons that are not evident to the committee, a site-specific analysis is required, the most significant area of inquiry would be physical oceanography. This can more appropriately be described in this instance by recourse to physical oceanographic literature and expertise than to short-term field surveys. Short-term field surveys cannot provide synoptic information. Furthermore, such oceanographic data acquisition is time consuming and costly.

There are ongoing environmental assessment projects that can possibly provide useful insights into the possible effects of ocean margin drilling. These are the Deep Ocean Mining Environment Study of the National Oceanographic and Atmospheric Administration (NOAA), and the Ocean Thermal Energy Conversion (OTEC) environmental assessment, also directed by NOAA.

Well Control

The single most important aspect of the safety of oil and gas operations is well control. The properties of hydrocarbons and of the formations in which they occur present the hazard that fluids (oil, gas, water, or various mixtures) will enter the borehole under pressure (a "kick"), and if uncontrolled, will be released to other formations, to the ocean, or to the air (a "blowout"). The consequences of blowouts are fire or explosions, changes in the specific gravity of the water under mobile rigs leading to loss of buoyancy, cratering of the seafloor, and pollution. Blowouts endanger workers, property and equipment, and the marine environment.

Well Control Technology for Drilling

The principal aspects of well control in drilling are: well design; selection of the proper equipment and its proper use; and, maintaining the pressure balance in the well. Maintaining the

pressure balance in the well constitutes well control in drilling; the other aspects serve to promote it. The primary tool for this is the drilling fluid. While drilling fluid serves other functions, such as cooling and lubricating the bit and enhancing penetration, the hydrostatic pressure of drilling mud in all wells prevents kicks. The mud is a constantly circulating medium which communicates indicators of downhole conditions, carrying warnings or evidence to the surface of impending kicks, such as gains in pit volume, or of lost circulation. The mud system also provides the means of killing the well or regaining control. This sounds simple, and in principle it is, but, in practice, maintaining the pressure balance requires constant attention, judgment (correct interpretation), and the correct response to indications of changing conditions in the well.

Careful design of the well is an important precursor to maintaining the pressure balance. Using geophysical, geochemical and geological information, it is necessary to construct as accurate a picture as possible of anticipated downhole conditions, and then to develop a plan of operations designed to cope with those conditions. By drilling a small pilot hole preceeding full-diameter drilling, information regarding pressured formations can be gained with least risk of loss of well control. The plan of operations should be bolstered with consideration of contingencies in operations and downhole conditions, and alternative responses to them.

While there is a large array of equipment that must be used in drilling, the basic items are simply described. It is necessary to have a reliable mud system (including pumps) because the mud system is the primary tool in well control. It is necessary to be able to shut-in the drill pipe with an inside blowout preventer (BOP), (essentially a check valve). It is also necessary to be able to seal off the annular spaces in the well; those spaces between the drill pipe and strings of casing, for example. Finally, the measurement of pressure and other downhole conditions and the use of that information in controlling the well is vital.

Well Control in Deep Water

Deep water drilling causes a well control problem that is unique as compared to normal drilling environments. In deep water, the fracture pressure of subsurface formations, as a function of depth below the mudline, decreases as the water depth increases. The problem is severe on initial penetration--the formation can stand a drilling fluid only slightly heavier than sea water (8.55 pounds per gallon or 1.03 kg/l). Depending on drilling rate, the weight of the cuttings circulated could add approximately 0.3 pounds per gallon (.04 kg/l) such that the equivalent density of the circulated sea water would approach 9.0 pounds per gallon (1.08 kg/l) density. Thus, it is necessary to drill without well control equipment until a formation is reached that is strong enough to withstand the hydrostatic pressure of a column of drilling fluid.

As the water depth increases, the pressure of the column of mud in the riser becomes greater. Mud that is too heavy will fracture the formation or cause lost circulation at the base of the marine conductor or surface pipe. Mud that is too light will allow the well to kick. As the water gets deeper, the effect of the mud in the riser becomes greater. In 2,000 feet (660 m) of water, mud much heavier than 9.6 pounds per gallon (1.15 kg/l) would cause lost circulation in shallow sediments. The depth of hole drilled for surface casing in the OMD Program is intended to be such as to provide a pressure integrity of 10.5 pounds per gallon (1.26 kg/l). Until the surface casing is installed, drilling must be performed without blowout preventers or a riser, because until that integrity is reached it is not possible to install well control equipment and have it function effectively. In 5,000 feet (1,500 m) of water, a pressure integrity of 10.5 pounds per gallon (1.26 kg/l) would be reached at 2,800 feet (850 m) below the mudline, while in 13,000 feet (4,000 m) of water this would occur at depths approaching 6,000 feet (1,800 m) below the mudline. Once formations of sufficient pressure integrity are reached, it is possible to install casing and the full complement of well control equipment.

The effect of deep water upon drilling operations is that:

- The mud weight in the shallow part of the hole must be lighter to avoid lost circulation.

- The first casing must be set deeper where formations are strong enough to support required mud columns.

- As the water gets deeper, there is an increased interval where it is not advisable to close the well.

- As the water gets deeper, there is an increased interval where the riser cannot be set, and spent drilling fluid must be deposited on the seafloor.

Another concern in providing well control in deep water centers on detection of warning signals and kicks. The long choke lines will increase circulating pressure losses and lower the maximum allowable operating pressure. Further, the rapid lengthening of the kick as it reaches the choke line makes the maintenance of proper well control more difficult. These factors add emphasis to the need for improved instrumentation, as discussed earlier.

Technical Aspects of Ocean Margin Drilling and Conformance with OCS Orders

There is no requirement that the Ocean Margin Drilling (OMD) Program must adhere to the OCS drilling and operating orders of the U.S. Geological Survey. However, these Orders reflect current best drilling practices, and the OMD Program intends to follow the best and

safest procedures. The committee was especially interested in how the OCS Orders compare with the intended procedures of the OMD Program, primarily because commercial drilling is moving into deeper water. The practices of the OMD Program, therefore, will likely set the stage for future commercial development.

One aspect of the proposed OMD program contravenes the U.S. Geological Survey's OCS Order No. 2, which requires that conductor and surface pipe be set and an annular preventer installed with conductor pipe and a full complement of blowout preventers, prior to drilling below 9,600 feet (2,900 m) below the seafloor. This rule applies to "shallower water" locations compared to the OMD Program locations. Enforcing these shallow-water-specific provisions on the OMD Program would not be safe practice. There is a provision of OCS Order No. 2, however, that acknowledges that all casing setting points should "be based upon all engineering and geologic factors, including the presence or absence of hydrocarbons, other potential hazards, and water depths." Also under this provision, the regional supervisor of the Geological Survey can approve the setting of casing and installation of well control equipment at depths that are in excess of those spelled out in OCS Order No. 2.

A requirement of the Geological Survey that is very germane to safe drilling is the preparation of a Critical Operations and Contingency Plan for Well Control. Detailed planning of drilling operations, especially those in new circumstances, is critical to their success. This involves preparing a detailed set of conditions, activities, and guidelines that will identify the most critical situations that may be encountered and what must be done to cease, limit, or not commence the operation. Activities that may need to be covered in the preparation of such a plan include:

- Running or pulling the riser;
- Running and cementing casing;
- Moving the vessel off location, repositioning, and reentry into the wellbore; and,
- Coring operations.

Some conditions to be considered for curtailing operations include:

- Unusual drilling conditions expected or encountered;
- Meterological or oceanographic conditions; and,
- Special equipment or personnel required for a particular operation.

Additionally, the individual who has responsibility for the overall drilling operation and who must make decisions on continuing or ceasing operations must be named and granted proper authority.

Possible conflicts that may arise between the scientists, the drilling foreman, or the vessel's captain need to be provided for by specific designation of the person in charge.

Unusual situations or combinations of situations occur often in the most routine of operations. This plan would be an attempt to anticipate problems and emergencies, and to assist responsible personnel in handling these critical matters. The remoteness, uniqueness, and combinations of geologic, meterological, and oceanographic conditions of this program, demand comprehensive contingency planning.

The Utility of Computer Simulations

Computer simulation of the control of deep water wells can be an invaluable aid in planning the well. At least one system is now available into which variables such as gas compressibility, solubility, temperature changes, mud models, etc. can be programmed. In addition to casing simulations in the design phase of the OMD Program, it would be useful to have that capability onboard the Glomar Explorer for the purpose of well planning, and for training.

Training and Qualification of Ocean Margin Drilling Workers

Accidents do not just happen. People cause them to occur, or engineered systems fail in some way. The OMD Program will place extraordinary demands on its operations personnel. They will be required to operate advanced state-of-the-art drilling equipment in an unfamiliar drilling environment, under occasionally hostile environmental conditions, and in logistical circumstances which may preclude frequent shoreside visits or logistic support.

All of these conditions pose challenges to the OMD Program in the selection, training, motivation, and qualification of operating personnel.

Because of the importance of the training and qualification of offshore workers, the committee intends to conduct a separate assessment of this topic within the scope of its study assignments. At this juncture, however, it is sufficient to note that the training and qualification of operating personnel is one-third of the triad that is important for well control: viz. the plan, equipment appropriate to the plan, and the people sufficiently trained and qualified to operate the equipment and implement the plan to provide for well control.

Providing for the training and qualification of personnel will take careful planning early in the OMD Program. It will be necessary for the NSF's System Integration Contractor (SIC) to develop a comprehensive approach to the training and qualification of ocean

margin drilling workers. The approach should address the selection of workers and their complete training in the operation of the specific equipment that will be used. It should also provide for on-site training and drilling in safe well control procedures during the course of operations.

SECTION III
CONCLUSIONS AND RECOMMENDATIONS

The conclusions provided in this section are based on information in this report. Several of the conclusions are followed by recommendations which are intended to assist the National Science Foundation in its safety considerations in planning the proposed Ocean Margin Drilling (OMD) Program. The conclusions are presented under general topical headings reflecting the issues raised during the committee's deliberations of 20-21 October 1980.

The Importance of Safety to Program Success

The committee concludes that a leading, possibly the most important, influence affecting the continuity of government and industry support of the Ocean Margin Drilling (OMD) Program will be the ability to assure that drilling and coring will be conducted in an environmentally and operationally safe manner. This assurance is equally a factor in maintaining foreign cooperation and participation. The program will face major technical challenges in its operating conditions--a combination of ocean depth and subbottom penetration. It will establish precedents in the nature of its program support--using joint government and U.S. industry financing and technical guidance. Program success and continuity will be dependent on the system, procedures, and expertise providing well control and preventing blowouts, which, the committee believes, pose the greatest risk to personnel and the environment.

> The committee recommends that the OMD Program comply with the intent and principles set out in the Outer Continental Shelf (OCS) orders, regulations, codes, and standards issued by the federal government, even though many of these regulations do not extend jurisdictionally beyond the ocean shelf. The committee recognizes that some specific requirements of the OCS orders that are established for shallow water operations will not be technically feasible nor applicable to the

> OMD Program--such as the requirement for using blowout prevention devices during the early stages of penetration beneath the seafloor. Therefore, the extreme depth of OMD Program operations will require setting out a proposed casing and well-control plan for review as to the adequacy for each specific site.

Regulatory Jurisdiction

The committee notes that U.S. Coast Guard and U.S. Geological Survey administered regulations constitute, directly and through memoranda-of-understanding with other agencies, the major legislative requirements pertinent to the OMD Program. It is concluded that the Coast Guard requirements are commonly imposed on government operated research vessels and the administrative process for safety and vessel review and inspection is clear; however, the USGS's process for review and assessment of drilling plans is designed to be applied to offshore commercial structures and personnel engaged in oil drilling and production and does not clearly fit research drilling operations. There is no USGS organizational structure directly applicable to the OMD Program.

The predecessor to OMD Program, the Deep Sea Drilling Program, by means of the JOIDES Safety Panel, provided several of the functions undertaken by each district office of the USGS for new drilling activity in the OCS, viz., to review and assess the nature and characteristics of the formations and to evaluate other information important to safe drilling operations at the proposed drilling site. This scheme, used in review of <u>Glomar Challenger</u> operations, has provided a conservative and effective safety review capability, albeit under a less demanding set of environmental parameters for deep sea drilling.

The Safety Review Panel should be constituted from its outset to be credible to all host countries and internationally as well. Host country representatives and also USGS personnel need to participate in safety review activities. The Safety Review Panel needs to consider host country or international regulatory requirements as appropriate. Further, the drilling plan documents prepared by project personnel and reviewed by the Safety Review Panel need to be forwarded to the appropriate national regulatory agency. This maximizes the opportunity to have a single homogeneous doctrine for project personnel to plan against, to train for and to operate with.

> The committee recommends that the NSF use a safety review process and organization which expand on the process used with the deep sea drilling program, in conjunction with the drilling plan. The safety planning process should involve host countries, and have international credibility. In addition, it is recommended that the OMD Program adhere to permit

review requirements designated in the USGS's OCS Orders (Ref 30 CFR 250). It is recommended that the Safety Review Panel include USGS personnel who will serve in recognized capacity as the USGS representative. Further, since well control technology procedures and training are critical to the program, it is essential that the Safety Review Panel include appropriate engineering and training expertise.

Environmental Impact of the Ocean Margin Drilling Program

The committee concludes that routine operations in drilling on the ocean margin for cores will have very little impact on the open ocean ecosystem, to the extent of being difficult to detect. Also global impact will be negligible since only ten sites are to be drilled world-wide. However, thorough assessment of environmental impacts will assist safety planning by identifying some concerns in a timely way.

An accident or loss of control resulting in loss of fluids or emission of hydrogen sulfide gas could have significant impact on benthic fauna (from formation waters) in concentrated areas of limited radius or blowouts could result in the usual oil spill effects. The committee concludes, from evidence demonstrated in recent studies and reports, that existing cleanup procedures for oil are not feasible in the open sea where wave heights and characteristics usually preclude effective use of existing systems.

In regard to the environmental analysis or impact at specific sites, the significant aspects are local ocean dynamics which may be obtained from physical oceanographic literature where available. Where available information is completely inadequate, special studies may conceivably be needed in advance of drilling. However, in the committee's view, new on-site surveys of plankton and benthos will add little to the information already available for use in an environmental analysis in advance of drilling.

Application of Deep Sea Drilling Technology

The committee concludes that the control of downhole pressure is critical to safety and the physical constraints allow for little error in knowledge of the formation to be penetrated. Therefore, rigorous geological assessment of the proposed drilling site is viewed as being the first strategic defense against high pressure and hydrocarbon zones, and, in addition to surveys, instrumentation now under development should assist in the operational or tactical response to potential kicks.

> The NSF should give special consideration to applying an adequate well control procedure when drilling the first hole below the mudline and until reaching a casing seat integrity adequate to contain hydrocarbon kicks and to use a riser. The committee recommends NSF continue to emphasize detailed geophysical and geological site surveys and use a small diameter test hole to acquire shallow penetration information before commencing full-scale drilling for scientific cores. The OMD Program should use the best available and safest technology (BAST), including adequate quality assurance programs, and acceleration of promising technology for well control.

Criteria for Stopping Operations

The committee concurs in the policy of the OMD Program to halt drilling and further penetration upon encountering hydrocarbons or hydrogen sulfide. The implementation of this policy through operating procedures is dependent on the establishment of response actions related to the presence of levels of these substances. This is dependent on the capabilities of the system and operating personnel to detect the presence of these substances, and on an evaluation of the threat posed by their presence.

> The NSF should develop operational procedures to implement its policy to halt operations in the presence of hydrocarbons or hydrogen sulfide. The procedures should include the establishment of response actions related to the presence of levels of these substances, with specific assignment of responsibility for the decision to resume operations after they have been halted because of the presence of hydrocarbons or hydrogen sulfide. The response actions should be based on the capability of systems and personnel to detect and respond to the presence of these substances, and on an evaluation of the threat posed by their presence.

Training

The committee has noted that an integrated and continuous training program is essential to successful and safe operations; the ingredients and character of such a training program is being investigated in greater detail as part of the committee review of engineering-related issues in the OMD Program.

APPENDIX A

INTERNATIONAL CONVENTIONS AND AGREEMENTS

International Convention on Civil Liability for Oil Pollution Damage, 1969 (CLC)	Ship owner liable for damages resulting from oil spills up to $160/ton of the vessel, or $16.8 million, whichever is less. Has not been ratified by the United States.
International Convention on the Establishment of an International Fund for Compensation for Oil Pollution Damage, 1971 (Fund Convention)	Supplements 1969 limit: pays spill claims up to $54 million, indemnifies ship ower up to $120/ton of the vessel or $10 million, whichever is less. Has not been ratified by the United States
International Convention for the Prevention of Pollution from Ships, 1973 (MARPOL)	Oil discharges from any tanker may not be greater than 1/30,000 of cargo during ballast voyage; no oil discharges in designated environmentally sensitive areas; oily wastes must be kept onboard and discharged at reception facilities; segregated ballast tanks required on all new tankers above 70,000 DWT. Recently ratified by the United States (August 1980).
Protocol of 1978 Relating to the International Convention for the Prevention of Pollution from Ships, 1973 (MARPOL Protocol)	All new crude-oil carriers over 20,000 DWT must have segregated ballast tanks, crude oil washing systems, and eventually, all tankers over 40,000 DWT must have one or the other. Recently ratified by the United States (August 1980).
International Convention for the Safety of Life at Sea, 1974 (SOLAS)	Among others, standards for vessel design, navigational safety, cargo loading and transport. Ratified by the United States.
Protocol of 1978 Relating to the International Convention for the Safety of Life at Sea, 1974 (SOLAS Protocol)	Inert gas systems will eventually be required of all tankers over 20,000 DWT, as well as specified steering equipment, redundant power system for rudder, all vessels over 10,000 GRT. Ratified by the United States.
Agreement of Cooperation between the United States and the United Mexican States Regarding Pollution of the Marine Environment by Discharges of Hydrocarbons and other Hazardous Substances, 1980	Provides for a joint response plan to be worked out between appropriate agencies of the two countries, establishment of a joint response center, and a joint response team.
Convention for the Protection of the Mediterranean Sea against Pollution and Protocol for the Preventipn of Pollution of the Mediterranean Sea by Dumping from Ships and Aircraft	Prohibits dumping of various substances, including crude oil and petroleum derivatives; special permit required for dumping others.
Protocol concerning Cooperation in Combatting Pollution in the Mediterranean Sea by Oil and other Harmful Substances in Cases of Emergency	Regional center has been established at Malta to advise on pollution incidents, actual and threatened.
Kuwait Regional Convention for Cooperation on the Protection of the Marine Environment from Pollution	From all sources.
Convention on the Protection of the Marine Environment of the Baltic Sea (Norway)	

APPENDIX A (continued)

Convention on the Protection of the Environment between Denmark, Finland, Norway, and Sweden	From all sources.
Agreement concerning Cooperation in Dealing with Pollution of the North Sea by Oil; Convention for the Prevention of Marine Pollution by Dumping from Ships and Aircraft; Convention on Civil Liability for Oil Pollution Damage from Offshore Operations.	

Conventions are being established for other regional seas--the Red Sea, Persian Gulf, South Pacific, West African Coast, east Asian waters, and the Caribbean (where marine sanctuaries are being established)--as the United Nations Environmental Program's regional studies proceed.

REFERENCES

1. The regulations that apply to the MODU as a ship can be found in 46 CFR 107-109--inspection and certification, design and equipment, and operations (these are specific to MODUs, but similar to the regulations governing merchant ships); 46 CFR 50-60--marine engineering, specifications, standards, codes; 46 CFR 42-46--load lines, and others.

2. The Stanwick Corporation, "Shipboard Training and Maintenance for Merchant Vessel Survival Equipment," Report prepared for the Office of Research and Development, U.S. Coast Guard, U.S. Department of Transportation, Arlington, Virginia, The Stanwick Corporation, October 1979, p. 1-1.

3. Executive Order No. 12114, January 4, 1979.

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